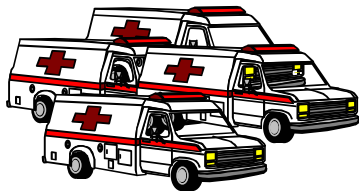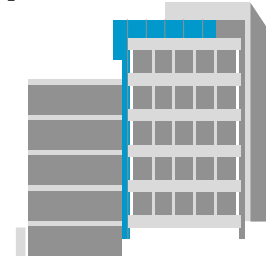# Biomedical Applications of the Next Generation Internet
Medical Nomadic Computing Applications for Patient Transport

A Project of the National Library of Medicine, The University of Maryland Medicine, The Maryland Center for Telecommunications Research, and Northrop Grumman

Mobile Wireless Communications

- Wireless transmission of audio, video, and vital sign data
- Integration of existing commercial technologies

- Modular, standards-based, open-system components
- Leverages existing communications infrastructure

NATIONAL LIBRARY OF MEDICINE

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University of Maryland Medicine

Any *time-sensitive or remote care/supervision* situation where remote expertise is needed - including Non-Medical Scenarios

There are multiple critical care and time-sensitive emergency situations where key expertise is not available to the on-site response team.

Wireless data transmission can be used to bring remote expertise and advice directly to the scene.

Need: Time-Critical Brain Attack

- Stroke is **#1** cause of adult disability (#3 killer)
  - ~ 1.2M strokes/TIAs per year in America alone
  - > 3 Million people living with the effects of stroke
- Stroke treatment costs more than $40+Billion/yr
- **80% of all strokes block blood-flow to brain**
- New treatments are available - if given *in time*
  - t-PA reduces disability - *if given within 3 hours*
  - majority of patients miss the 3 hour treatment window

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- Any *time-sensitive or remote care/supervision* situation where remote expertise is needed - including Non-Medical Scenarios
  - Long distance transports
  - Trauma calls
  - Pediatric care, high-risk deliveries, others
  - Bomb threat assessment/First scene responders
  - Combat casualties
  - WMD, scene command, etc.

Project History: MTS Prototype

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Mobile Wireless Communications

- Wireless transmission of Audio, Video, and Vital Sign data
- Integration of existing commercial technologies
- Modular, standards-based, open-system components
- Cost-sensitive approach

Ambulance Configuration

Digital Camera
Microphone
Speakerphone

TV
VCR

Video and Communication Computer

- Audio
- Video
- Patient Data
  - Records
  - Numerical VS
  - Waveform VS
  - Blood Chem

Patient Vital Signs Monitor
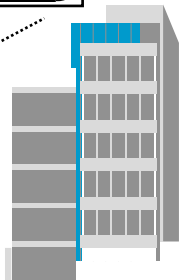
Hospital Configuration

Phone Lines Data In

NT Server

Hospital Intranet Secure Link

Browser + Java 'Applet'

Web Server

'Push' Server

SQL Database

Physician's Desktop "Intuitive Interface"

Ambulance Configuration

Speaker-Phone Microphone Digital Camera
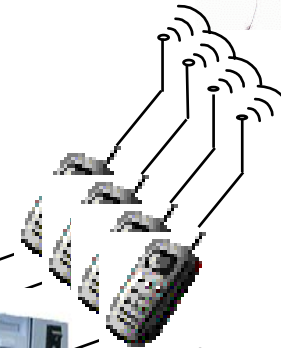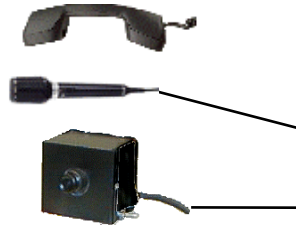
4 digital cellular phones

Video and Communications Computer

- **Audio**
- **Video**
- **Patient Data**
  - **Records**
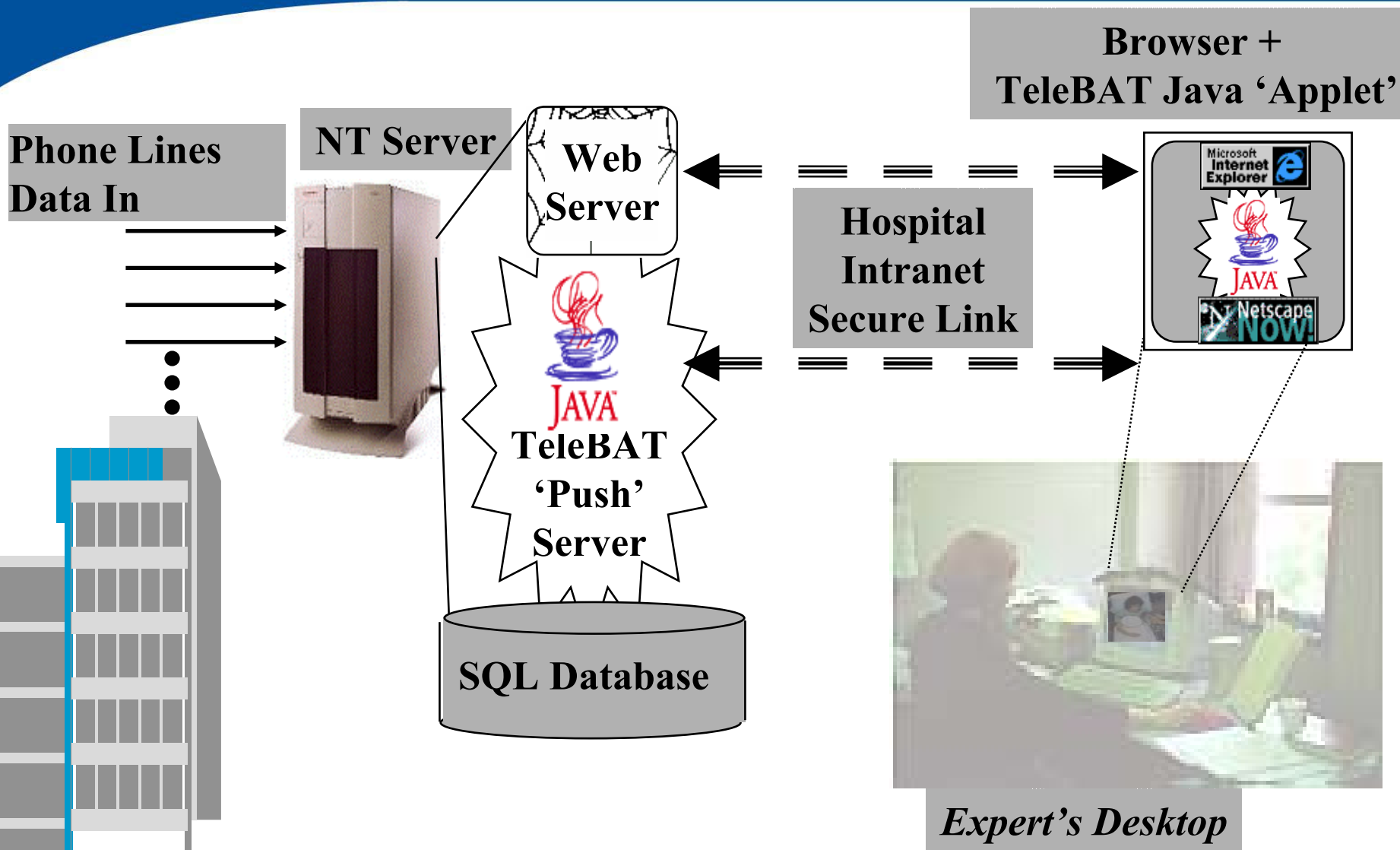 - **Numerical VS**
  - **Waveform VS**
  - **Blood Chem**

Patient Vital Signs Monitor

Receiving Facility

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Browser + TeleBAT Java 'Applet'

Phone Lines Data In

NT Server

Web Server

Hospital Intranet Secure Link

TeleBAT 'Push' Server

SQL Database

Expert's Desktop

En-Route Remote Neurological Exam

- **Demonstrated Clinical Value**
  - NLM Stroke Transport Research using NIH Stroke Scale
    - Tested through >24 Patient Transports
    - Results: deemed of significant value in aiding diagnostic decisions and reducing time to treatment
  - Disaster Management
    - Tested in conjunction with a BWI Fire&EMS Field Exercise (multiple mass casualty scenarios)
    - Results: transmitted data deemed of significant value in aiding diagnostic decisions

1

2

3

MTS Findings: QoS is Critical

> Transmitted data has *significant diagnostic value, but...*
>
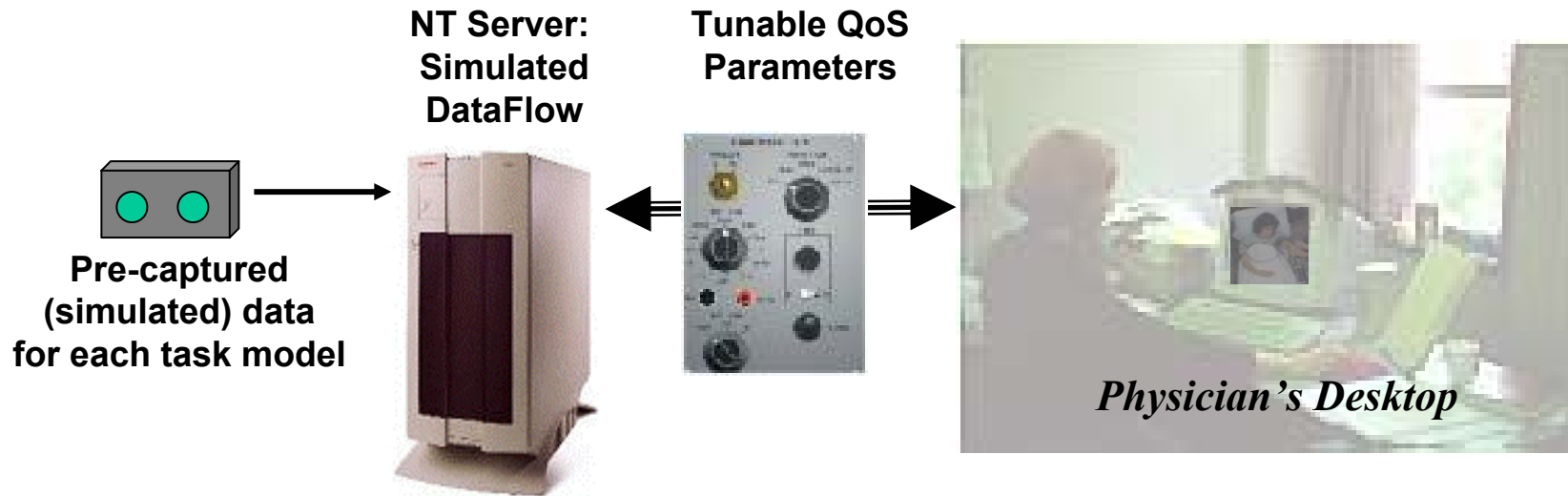> Quality of Service (QoS) issues limited the utility

- Reliability
  - High transmission error rate
  - High disconnection rate
  - Embedded systems issues

- Bandwidth/Data Throughput
  - Low bandwidth = limited data throughput
  - Unpredictability of bandwidth availability

- Total rewrite of applications code
  - Current Java enhancements
  - Superior control of underlying communications

- Leverage Superior Commercial Fractal/Wavelet Compression
  - 1frame/10 seconds => ~2frames/second (or better)

- More Stable Mobile Systems
  - Modernize the platforms and services

- More Robust Wireless Connectivity/Throughput
  - Migration to IP-based communications
  - Management of overlapping wireless coverage

- Reduce Size & Weight to Support Out-of-Vehicle At-Scene Models

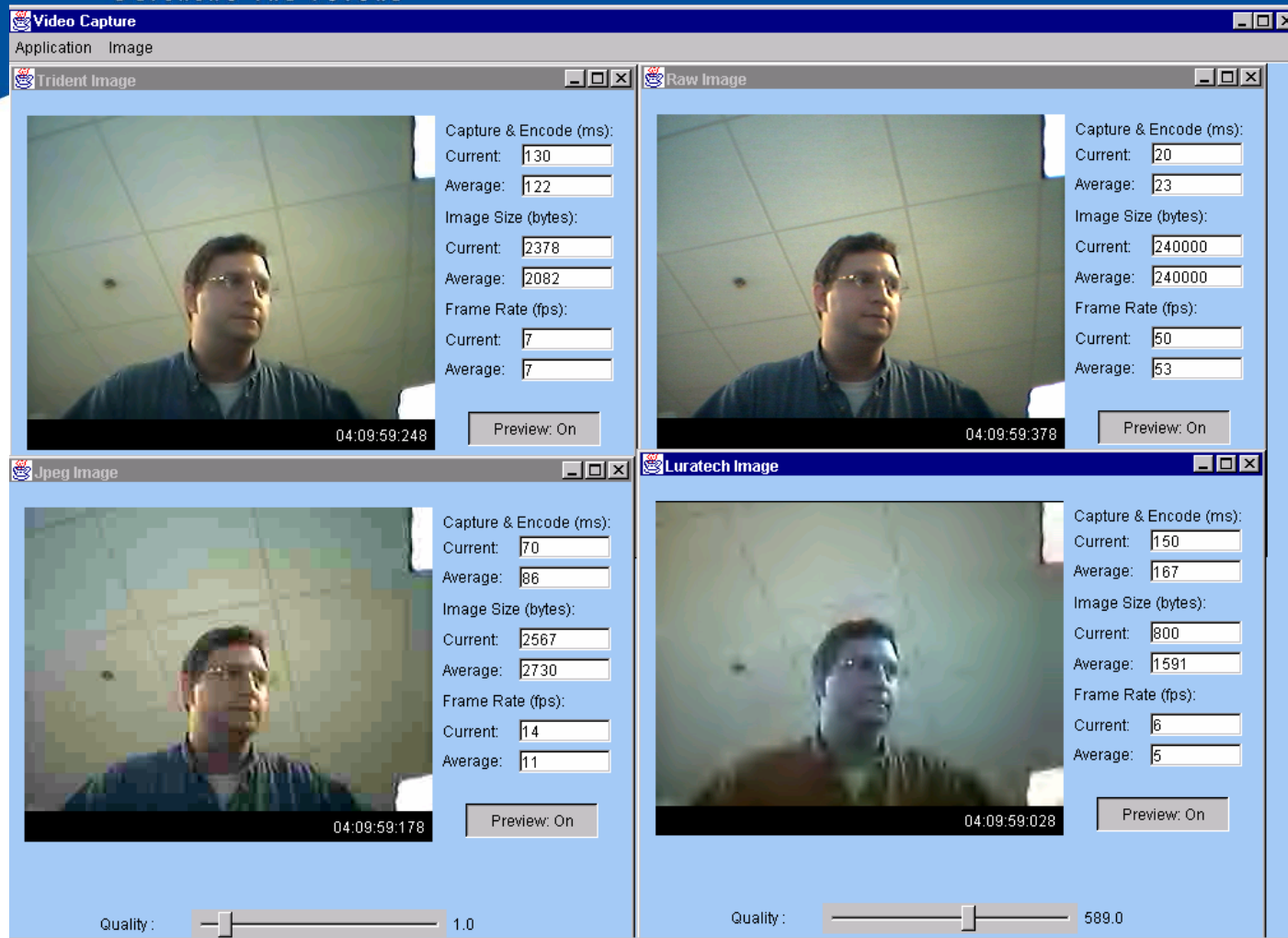# *QoS Control for Mobile Wireless Data Transmission*

- Integration of IP and dial-up connectivity

- Interactive control of transmission priorities

- Transmission layer-aware application

- Prioritization of data packets/channels

- Intelligent packet routing for higher bandwidth/reliability of end-to-end connection

- Secure protocols

Project Quality of Service Simulator

**NT Server:
Simulated
DataFlow**

**Tunable QoS
Parameters**

**Pre-captured
(simulated) data
for each task model**

Physician's Desktop

**Allows determining the *requisite*
QoS for each task model**

Java Compression Comparison Toolkit allows *objective AND subjective* comparison of codec performance
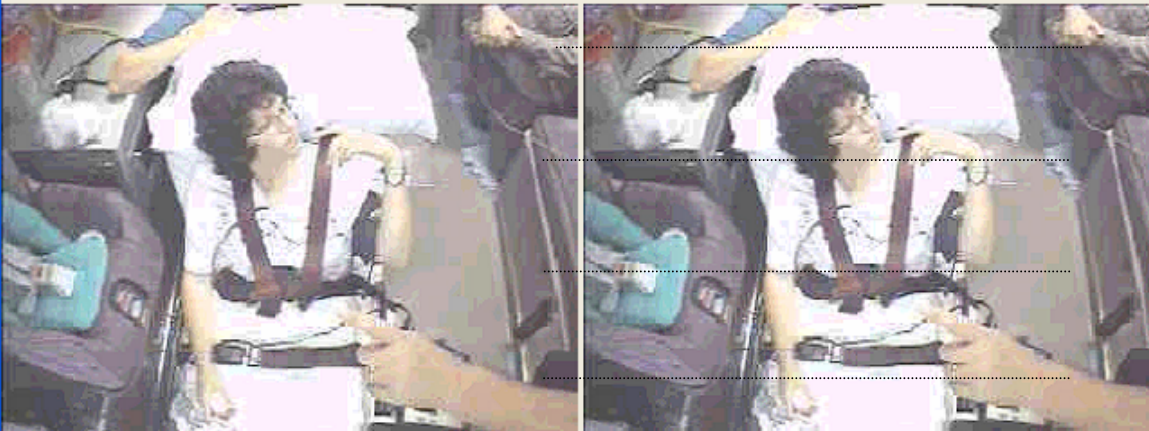
Modular Viewer Adjustable QoS

Bi-Directional QoS Controls and Region of Interest Selection

Multi-channel Vehicle Transmission System with QoS-savvy Comm

QoS Optimizing Packet-Packing

Queue:41	Channel	Packet	Time (ms)	Average (ms)	Failed
675 : 5/5	Wireless Modem	1024 : 3/5	1062	844	0
668 : 1/1	Wireless Data Modem 1	1024 : 4/5	3392	1268	0
1024 : 1/5	Wireless Data Modem 2	1024 : 2/5	2069	2841	0
1024 : 2/5	Wireless Data Modem 3	589 : 5/5	3842	3268	0
1024 : 3/5	Wireless Data Modem 4	994 : 1/1	2463	2843	0
1024 : 4/5					
689 : 5/5					
694 : 1/1					

Preview | General Props | Video Props | Vital Props | Mobile Communications

Queue **Packet-Packing** **Multi-Channel Transmission** **Reassembly**

1 2 3 4 5 6 7 8

Significant reduction in number of packets that must be transmitted
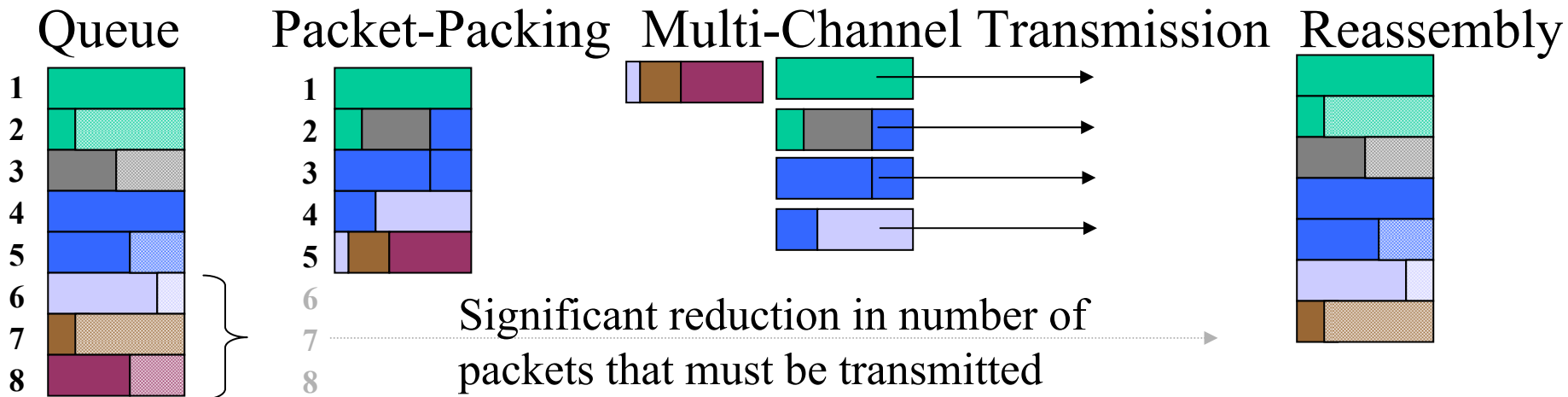
End-to-end latency and overhead is expensive

More efficient transmission by maximizing packet data payload

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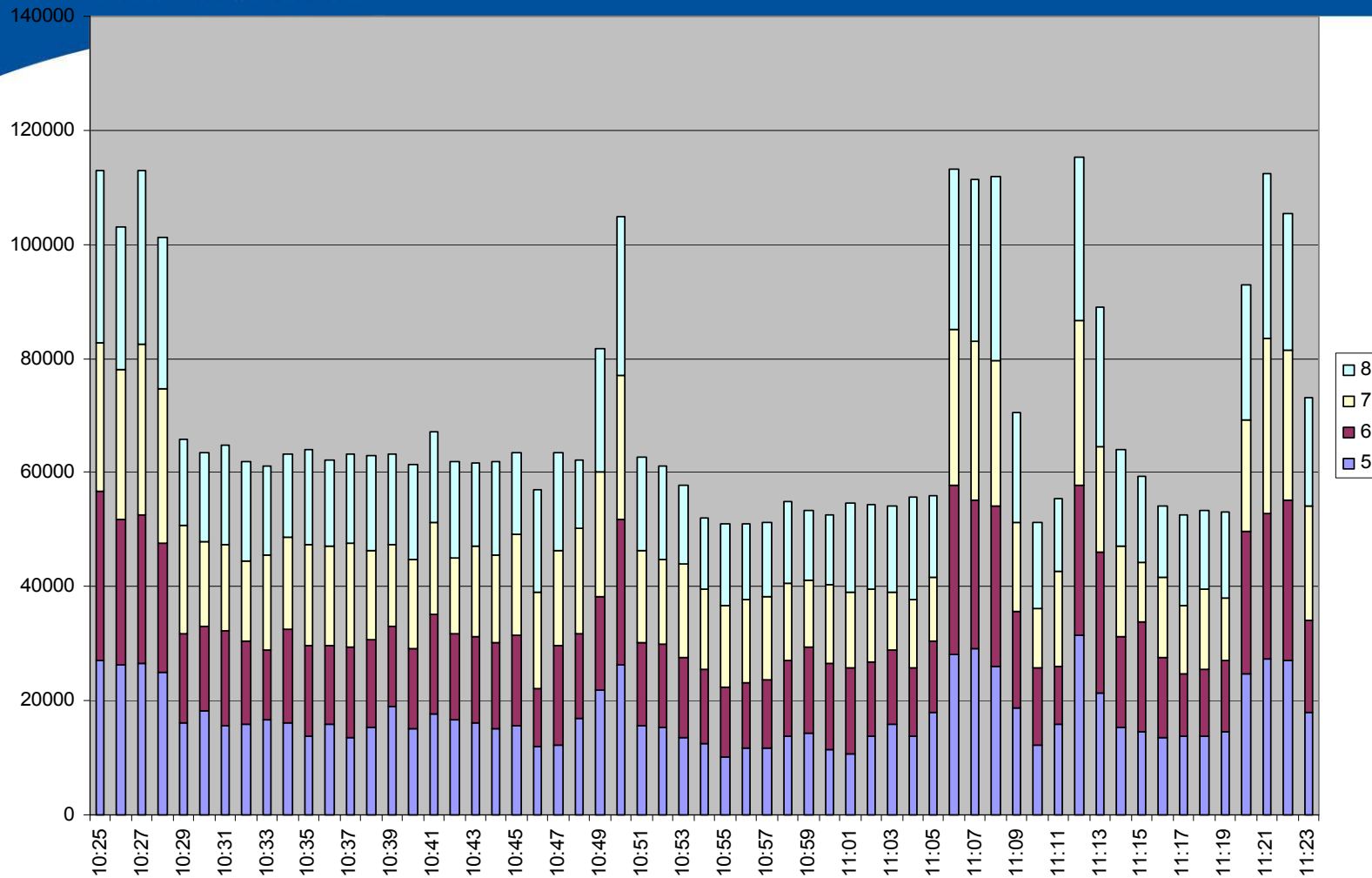
Aggregate bandwidth achieved using 4-cellular lines ~6Kb/s

Portable 'BackPack' Packaging of Mobile System

Note: Metricom Richochet IP Modem

Briefcase: Lightweight, self-contained, ruggedized packaging

No Change
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Two-Stage Data Transmission

Miniature Wireless Digital Camera *note smaller than 9volt battery

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Mass Casualty Incident scene command, two-stage transmission from scene to mobile Emergency Operations Center and relayed to receiving physicians at treatment facility

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Mobile contamination site two-stage transmission from scene to Incident Scene Commander at EOC, relayed to remote viewers at treatment facility

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- **Demonstrated use of multiple wireless communications schemes**
  - use of both analog and digital cellular systems from multiple providers
  - use of other wireless communications links in conjunction with cellular links
    - Verizon CDMA over IP aircard (equivalent to approximately 2 cell phones)
    - Metricom Ricochet IP network (equivalent to approximately 4 cell phones but network currently is inactive)
  - use of Bluetooth 802.11 wireless for short-range out-of-vehicle camera connectivity

- **Demonstrated concurrent operations of multiple systems/connections**
  - concurrent operations of 6 cell phones (through two different service providers) with CDMA over IP aircard
  - concurrent operations of 2 mobile telemedicine systems
  - use of out-of-vehicle EMT portable system with 4 cell phones

- **Demonstrated sufficient QoS for stroke and pediatric transport models**
  - average ~2 KBytes/second bandwidth with cellular connectivity
  - 2 to 3 frames/second [color 320x240 frames]: adjustable

Significant Accomplishments

- **Demonstrated requisite Quality of Service (QoS) through:**
  - Automatic connection/reconnection of communications links
  - Region of Interest (ROI) selection for higher detail image transmission
    - context driven by physician
    - allows physician to optimize bandwidth utilization to support changing needs
  - Automatic channel selection to optimize use of available bandwidth [dynamic adaptive line/channel management]
  - Individual picture selection for high priority image transmission [for store-and-forward to transmit more video than slow-scan images]
  - Compression Algorithm selectable/modular [implemented using an open standard codec so can dynamically change algorithms, image size, quality, and change any other settings that an individual algorithm may contain]
  - Automatic packet stuffing to maximize amount of data transmitted across available links
- **Demonstrated secure communications**
  - Wireless transmission security through
    - Proprietary (optimized compressed) communications software at Tx/Rx devices
    - Intercepted communications can not be reassembled without entire (decoded) data stream
    - Vendor provided digital cellular encryption
    - Hospital LAN security (via Firewall, IP-based authentication, Encryption)

- **Demonstrated concurrent transmission of dissimilar clinical data**
  - Slow and medium speed video
  - Audio
  - Digital vital sign data and waveform data (from Propaq equipment)
- **Demonstrated easy to use web-based physician interfaces**
  - Web browser based – intuitive point-and-click remote access
  - Remote access controls over Internet – secure from home or remote facility
  - Modular design to easily reconfigure for different clinical models
  - Developed and physician approved GUIs for stroke and pediatric transport task models
- **Demonstrated minimally intrusive EMT interface**
  - Ceiling mounted camera and microphone
  - Easy Propaq connectivity
  - 'turn-key' on/off operation

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- Vigilant security posture is not enough
  - On-going virus, worm, and intrusion attacks

- Dynamic network (in)stability
  - Shifting commercial systems stability
  - 'Own-worst-enemy' problem: in-house changes
  - Need for robust proactive error detection/notification
  - Need for calibration diagnostics

- Imaging 'artifacts' may be beneficial
  - Slight edge-enhancement eases subtle motion detection

- Commercial 3G and cellular-camera progress

Ongoing Research

- **Self-scaling Applications**
  - Have demonstrated two simultaneous mobile systems in operation
  - Scale to support regional fielding over multiple concurrent systems
- **Context-sensitive QoS Optimization**
  - Have demonstrated self optimizing communications software with region of interest selection (by receiving physician) and high priority image selection (by sending EMT or triggered by physician)
  - Receiving physician able to alter and reprioritize data transmission characteristics depending upon model context, e.g., adjust image quality vs. frame rate, waveform sensors on/off, etc.
- **Wireless Applications**
  - Integration of new additional wireless technologies (e.g., multiple IP connectivity)
- **Nomadic Applications (including Two-Stage Transmission)**
  - Have demonstrated nomadic (mobile telemedicine) applications
  - Additional two-stage (out of vehicle) work underway

Ongoing Research

- **Demonstrate Clinical Value for additional regional task models**
  - Focused regional 911 response (in Baltimore area)
  - En-route Task Models
  - At-Disaster Site Task Models

- **Ongoing System Enhancements**
  - Form-factor (size, weight, battery life)
  - Compression codecs and broader standards support

- **Integrate additional medical tools**
  - Blood chemistry monitoring device
  - Electronic stethoscope
  - Triage tag barcode reader

Questions?

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